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Status Report on Assembly of Lead-Free Project Test Boards

Joint Group on Pollution Prevention
Joint Council on Aging Aircraft

Lety Campuzano-Contreras
Materials & Processes Engineer
BAE SYSTEMS Irving (TX)

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Objective

- The objective of this presentation is to provide status on the manufacture of the Phase II JG-PP/JCAA Joint Test Protocol assemblies and point to future activities.

- As a result of two component problems with the test boards, a decision was made to split the development into two phases so that early data could be generated from the original boards and to minimize test costs to the consortium.

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Background

- Because of the drive in Asia and Europe for “green” electronic products, continued use of tin-lead solder presents business risks, including:
  - concerns about potential environmental legislation banning lead-containing products
  - risk of trade barriers and lost sales
  - reduced mission readiness
  - component obsolescence with lead surface finishes
- The Joint Group on Pollution Prevention began the Lead-Free Solder project in 2001 to have a better understanding of how some promising lead-free solder alloys perform when subjected to typical aerospace environmental conditions.
- JCAA joined JG-PP in May 1, 2003 because they saw the value of the lead-free solder project with regard to the numerous logistical and repair issues.
- Members of the combined team represent military services, NASA (**N**ational **A**eronautics and **S**pace **A**dministration), various defense, space and commercial contractors, and component and solder suppliers.

Background Continued

- To date, the project participants have:
  - Identified the performance requirements.
  - Identified tests for lead-free solders.
  - Identified the lead-free solder alternatives that would be tested.
  - Completed design of the test circuit card.
  - Assembled the 205 board test set and 92 SIR and EMR test boards.
  - Assembled 45 Phase II test boards that include hybrids and CSPs.
- Test set includes similar baseline tin-lead soldered boards.
- The materials were chosen based on initial environmental, safety, and occupational health screening data, as well as previous experience in Japan, Europe and other consortium using lead-free solders.

Background Continued

- The lead-free solder alloys agreed by the project stakeholders to be tested are as follows:
  - Tin-copper (stabilized) (99.3Sn-0.7Cu-0.05Ni) - wave and hand soldering
  - Tin-silver-copper (95.5Sn-3.9Ag-0.6Cu) - wave, reflow and hand soldering
  - Tin-silver-copper-bismuth (92.3Sn-3.4Ag-1.0Cu-3.3Bi) - reflow and hand soldering
- Rockwell Collins designed the test assembly and procured all components.
- BAE Systems Irving, formerly Boeing Commercial Electronics – Irving, agreed to assemble the test boards as our part in the consortium activities. Our facility and product were considered typical of factories producing a highly reliable product with enough volume to simulate a higher capacity production run.
- The project will generate critical reliability data on circuit cards manufactured and reworked with lead-free and eutectic tin-lead solders for military and space applications as documented in the Joint Test Protocol.

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Assembly Details

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Phase II Test Vehicle- Printed Wiring Assembly

PWB

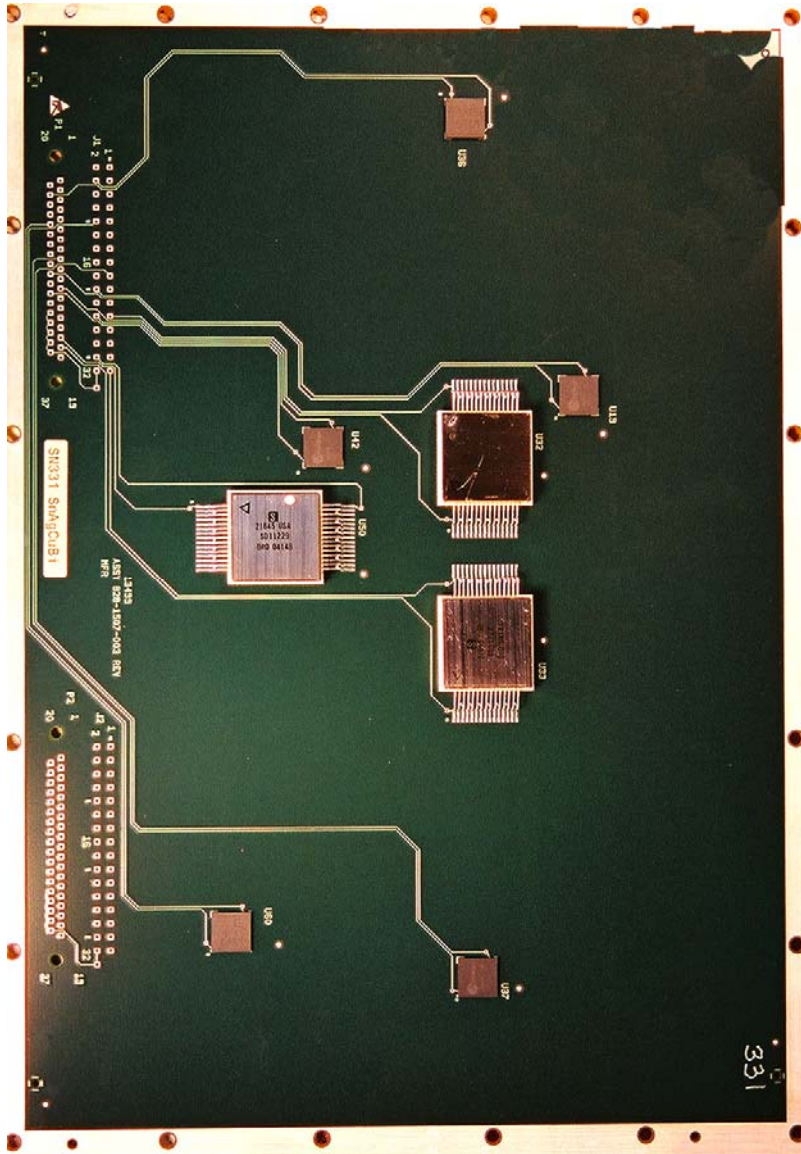
- 14.5”X 9”X 0.09”
- 6 layers
- Immersion Silver (Tg~170°C, GF)

PWA

- Hybrids and CSPs components
- Total Quantity: 30
  - SN:301-315 SnPb
  - SN: 316-330 SnAgCu
  - SN:331-345 SnAgCuBi

Lead-Free Solder Alloys

- Sn3.9Ag0.6Cu (SnAgCu or SAC)
- Sn3.4Ag1.0Cu3.3Bi (SnAgCuBi or SACB)



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Materials

Material	Reflow Soldering	Hand Soldering
Sn3.9Ag0.6Cu	X	Flux Cored Solder RMA
Flux	ROL1	R Heat Stabilized Resin
Sn3.4Ag1Cu3.3Bi	X	0.010 Dia. Wire
Flux	No Clean (RMA)	R Heat Stabilized Resin
Sn37Pb	X	Flux Cored Solder RMA
Flux	ROL0	ORL0

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Components- Phase II

Component Type	Component Finish
Hybrids	SnPb
	SnAgCu
	SnAgCuBi
CSPs A-CABGA100-.8mm-10mm-DC	SnPb
	SnAgCu

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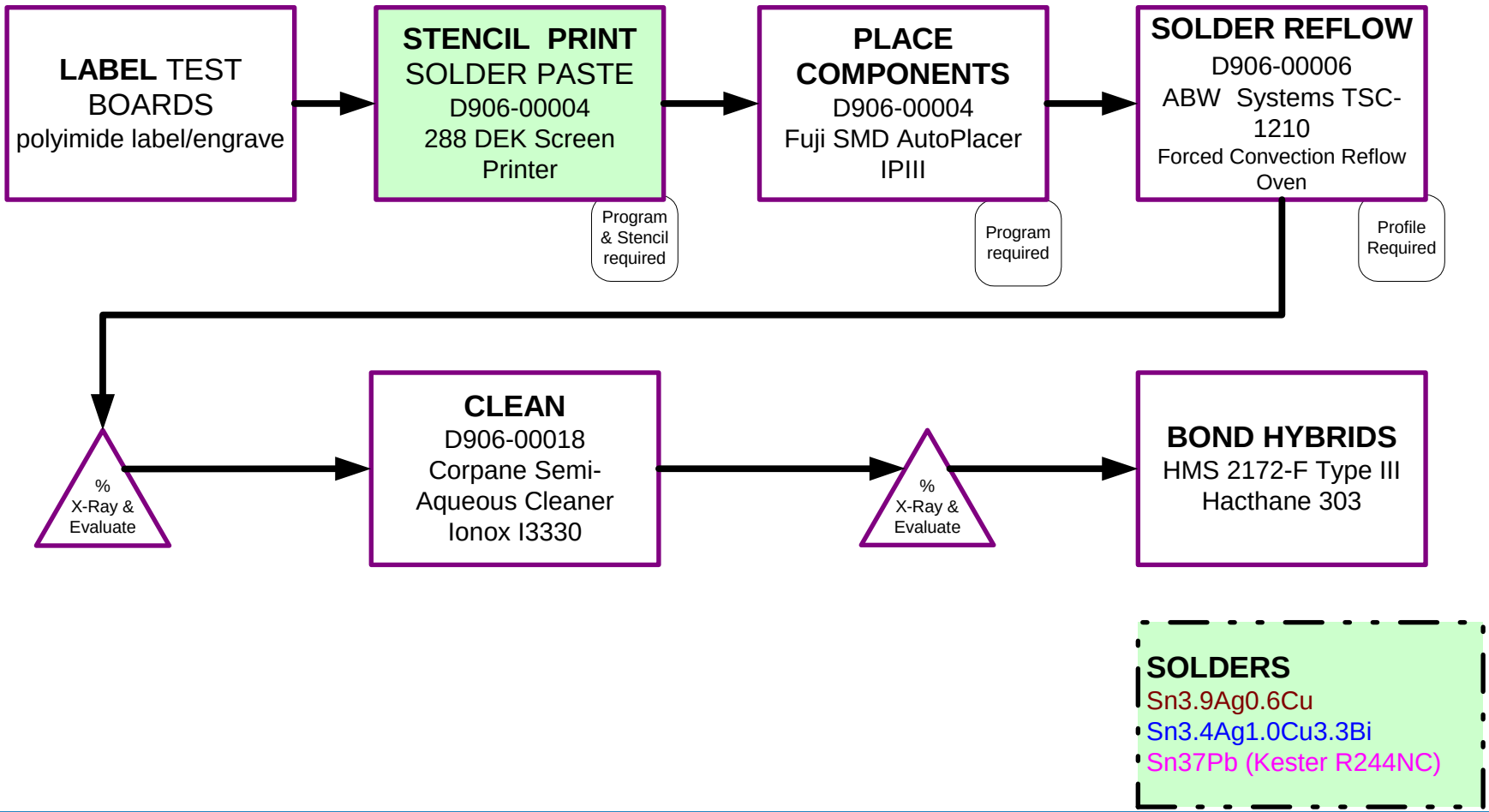
PHASE II LEAD-FREE TEST BOARDS ASSEMBLY FLOW



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Assembly Notes

- Only immersion silver, high Tg PWBs were used.
- Solder touch-up was performed with either SnPb, SnAgCu, or SnAgCuBi solder.
- Lead-Free wave solder was not necessary and was not performed on Phase II boards.
- Placement program was modified to remove all other components.
- Same solder stencil was used, the unused locations were taped.
- Nitrogen was not used during reflow.
- Hybrids were bonded using HACTHANE 303 after reflow soldering.

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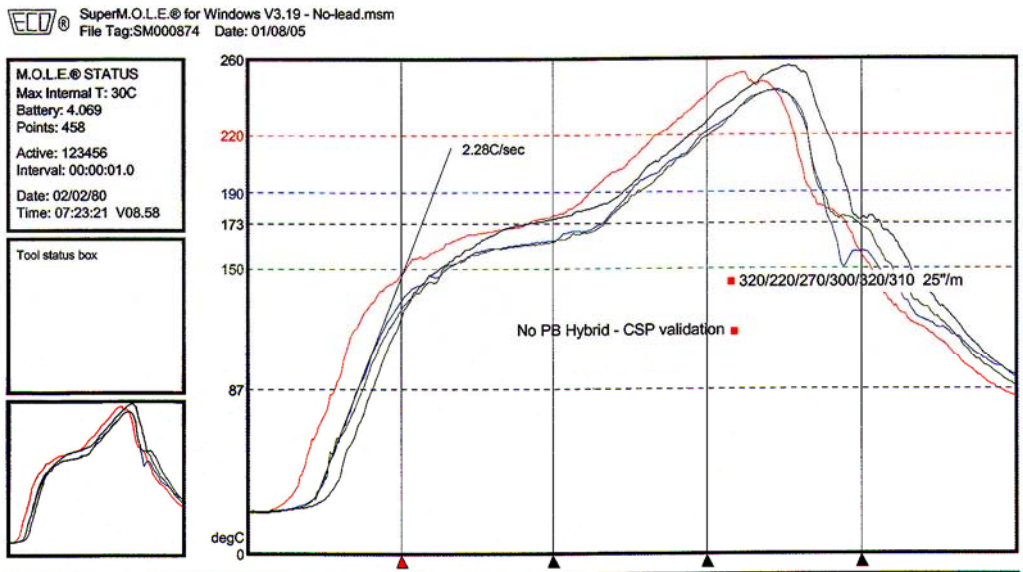
Tin-Silver-Copper (SnAgCu) and Tin-Silver-Copper-Bismuth (SnAgCuBi)

Reflow Oven Lead-Free Solder (SnAgCu & SnAgCuBi) Profile



	Value	C1 = 00:01:31r	C2 = 00:03:02r	C3 = 00:04:33r	C4 = 00:06:04r	Units
•	South of U37 CSP	147	178	241	158	degC
•	North of U32 hybrid	133	164	222	159	degC
•	North of U42 CSP	128	164	219	172	degC
◦	Open					
◦	Open					
•	North of U36 CSP	123	176	227	176	degC

Based on consortium agreed requirements:

Preheat = 60-120 seconds @150-190°C
Peak temperature target = 243°C
Reflow:
~20 seconds above 230°C
~30-90 seconds above 220°C

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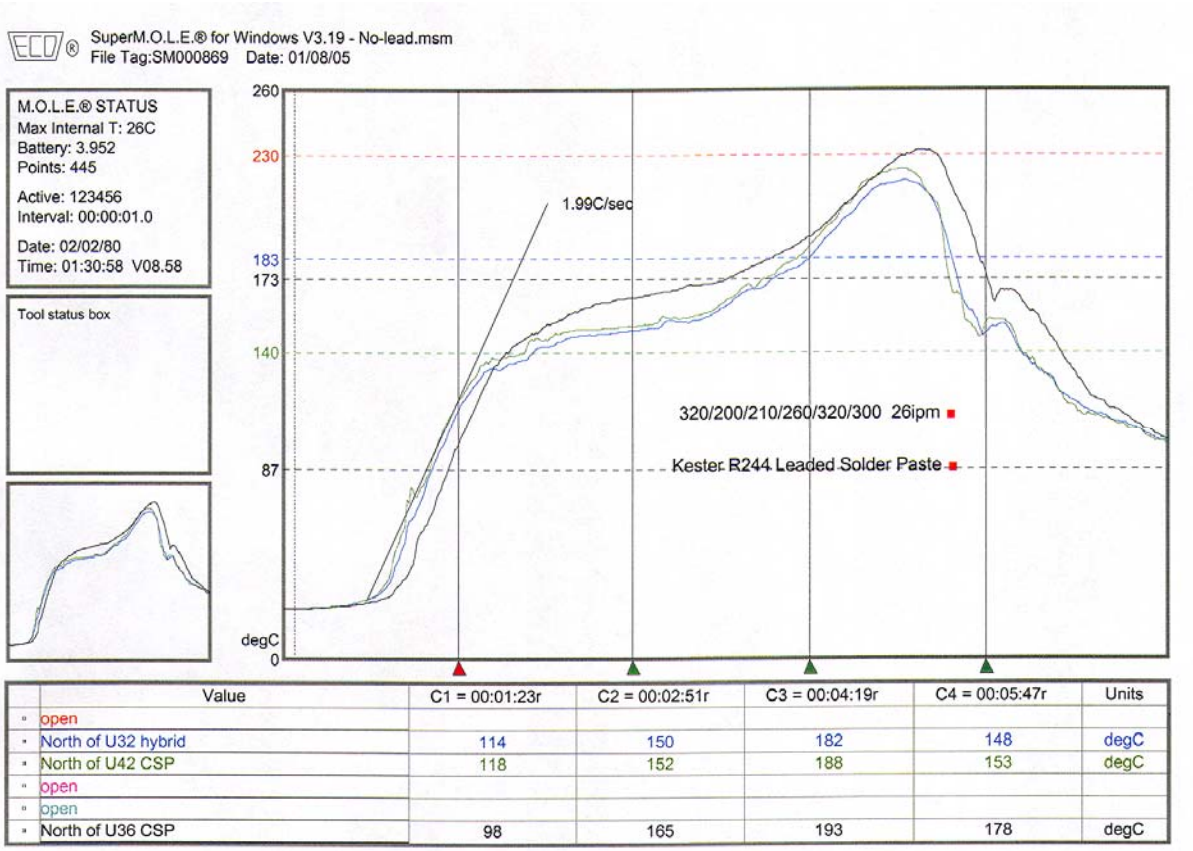
Tin Lead Solder (SnPb)

Reflow Oven SnPb Solder Profile



	Value	C1 = 00:01:23r	C2 = 00:02:51r	C3 = 00:04:19r	C4 = 00:05:47r	Units
▫	open					
▪	North of U32 hybrid	114	150	182	148	degC
▪	North of U42 CSP	118	152	188	153	degC
▫	open					
▫	open					
▪	North of U36 CSP	98	165	193	178	degC

Standard SnPb Profile

Preheat = ~ 120 seconds @140-183°C
Peak temperature = 225°C
Time above reflow = 60-90 sec
Ramp Rate = 2 °C/sec

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Results

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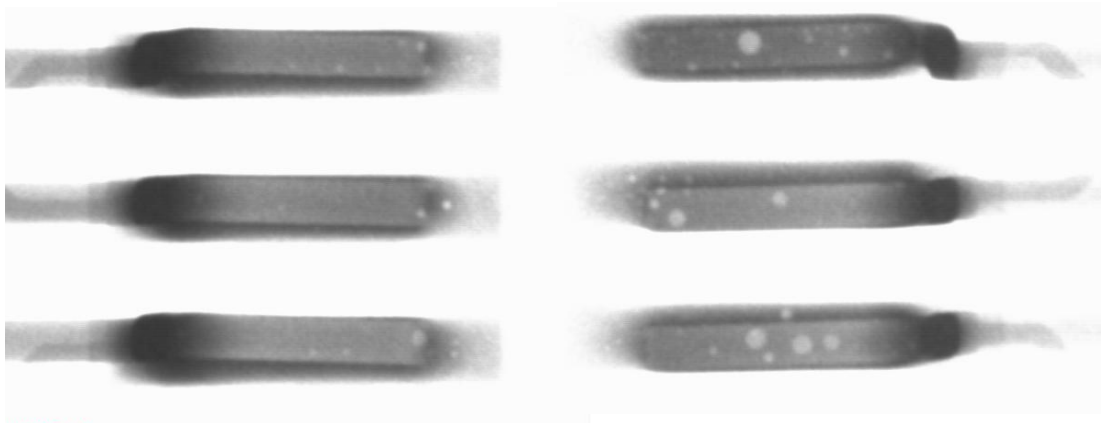
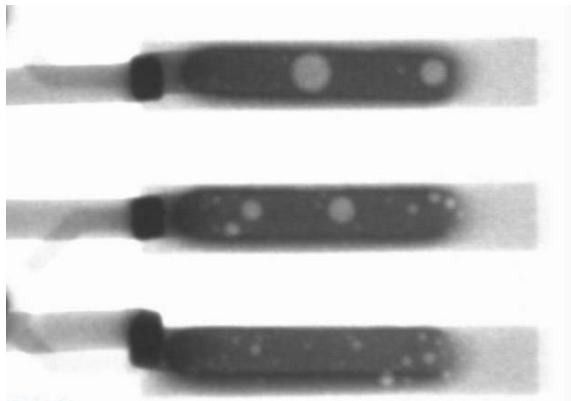
U33 Hybrid with SnPb, SAC and SACB solder



SN307 SnPb hybrid/solder

SN325 SAC hybrid/solder



Sn331 SACB hybrid/solder

Immersion silver PWB

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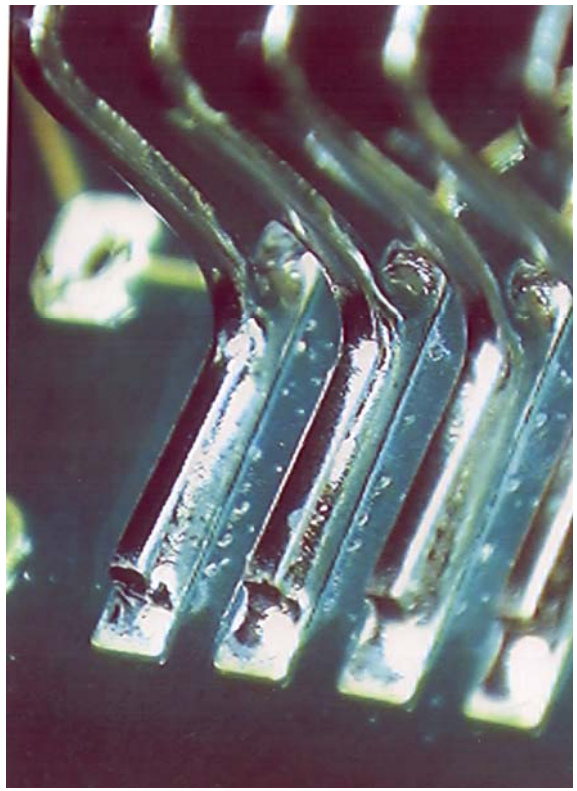
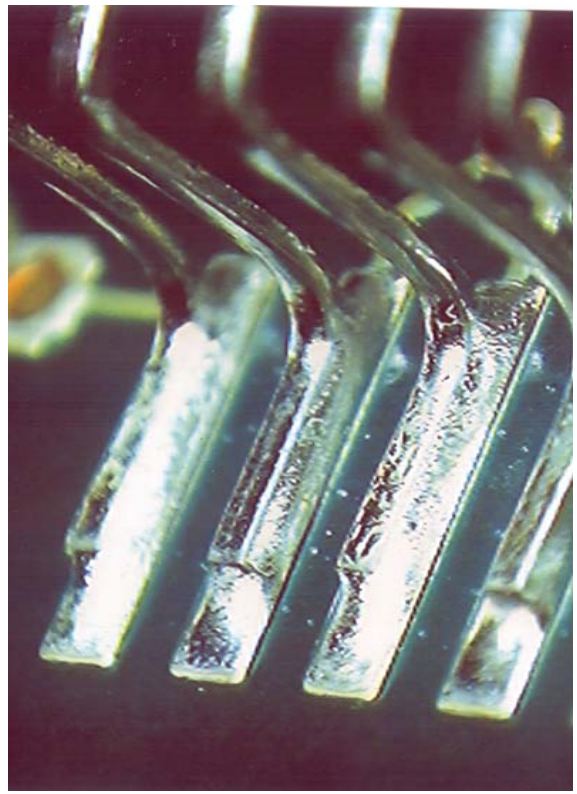
U33 Hybrid

SN307 SnPb U33



SN324 SAC U33



SN331 SACB U33

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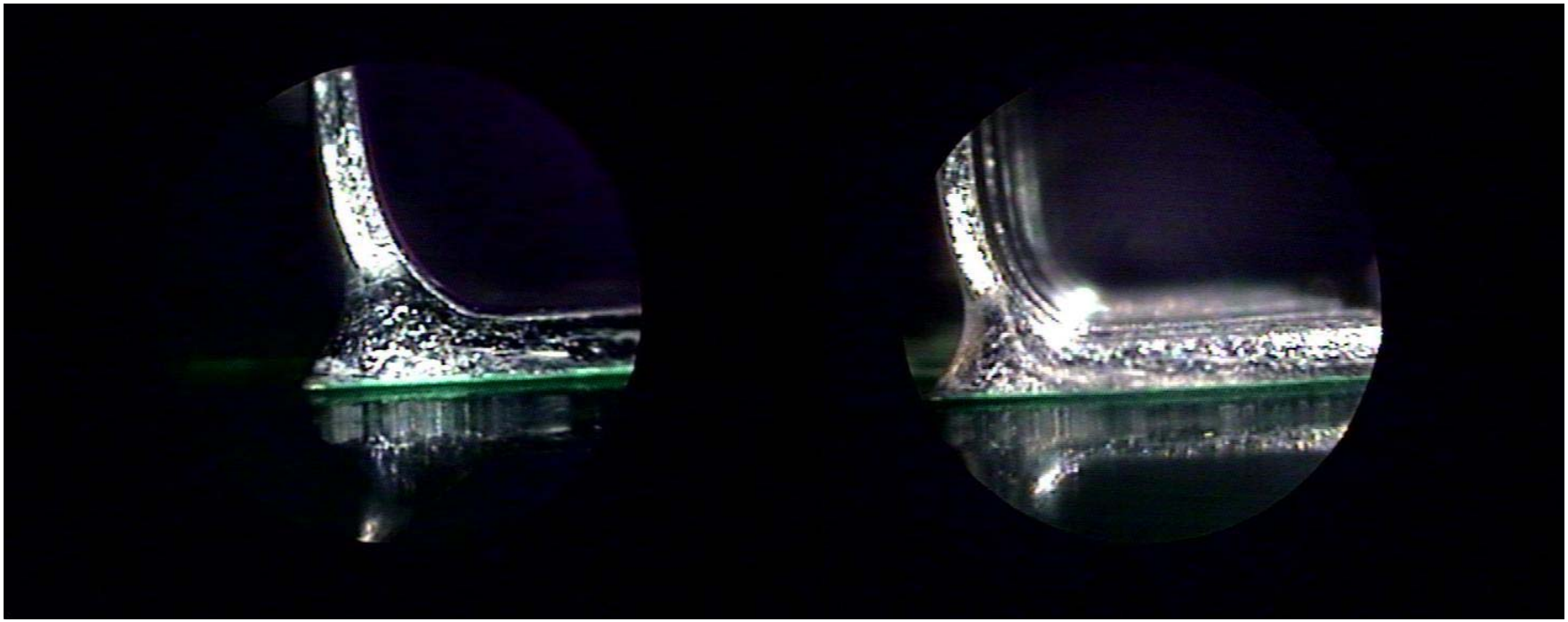
SACB



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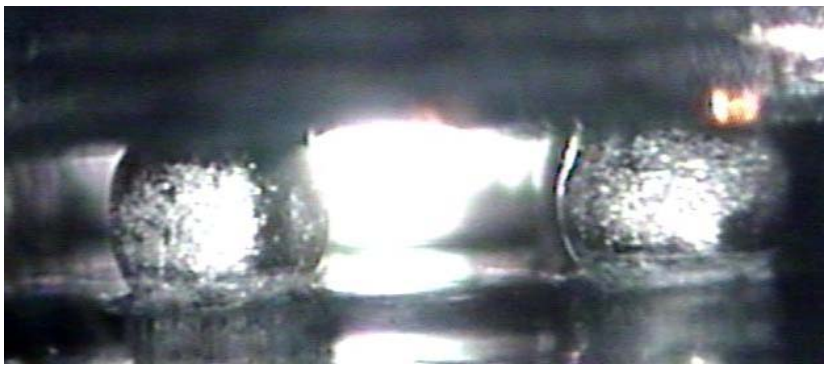
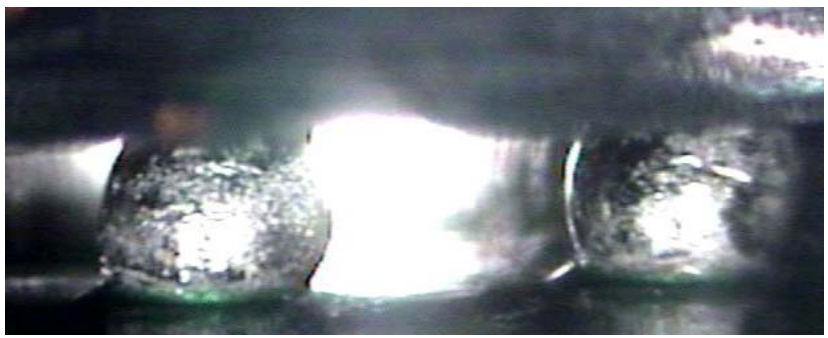
CSP U42

SN307 SnPb U42



SN325 SAC U42



SN332 SACB U42

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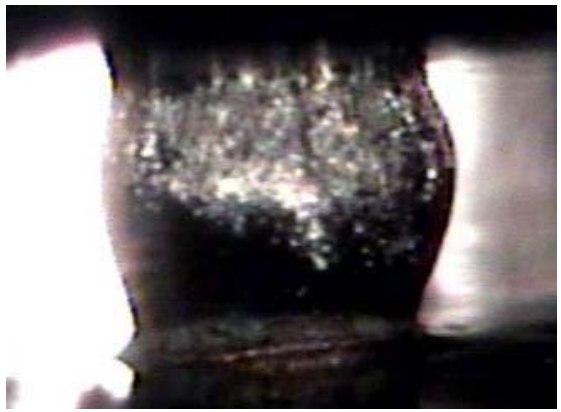
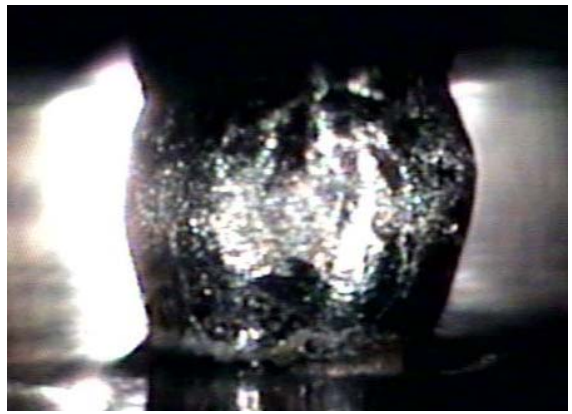
CSP U36 SnPb, SAC SACB

SN 307 SnPb



SN325 SAC



SN332 SACB

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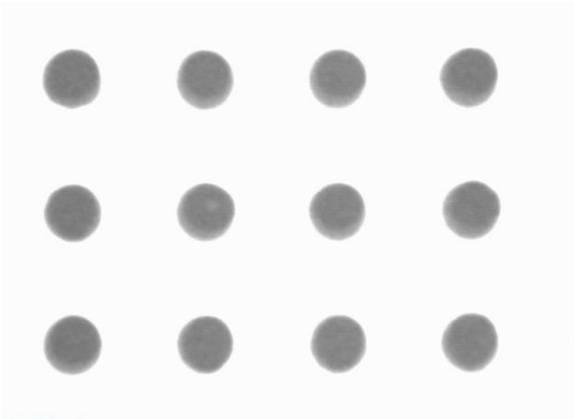
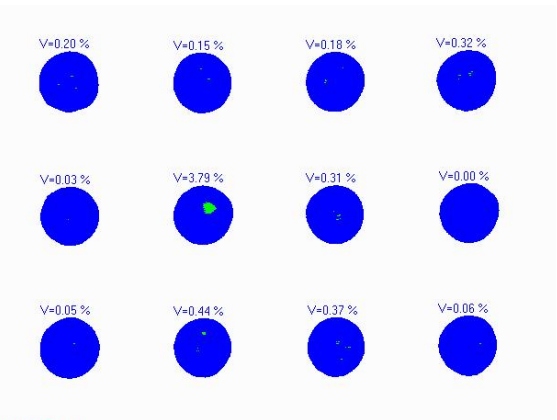
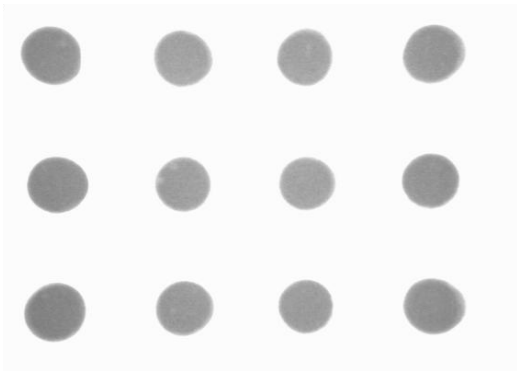
U36 CSP

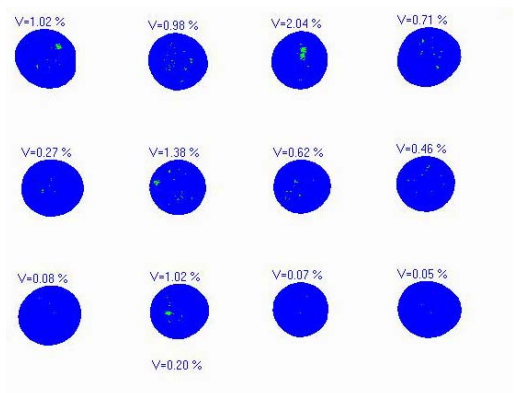


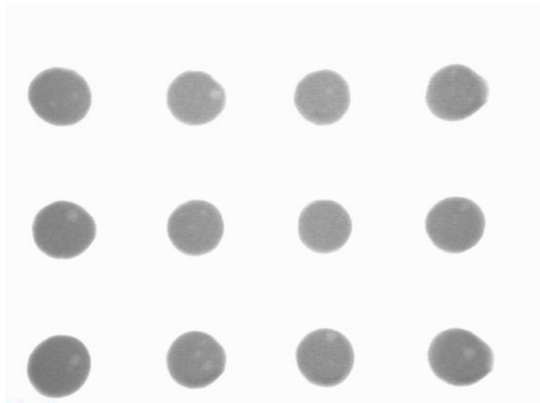
SN308 SnPb balls/solder
0 - 4 void percent



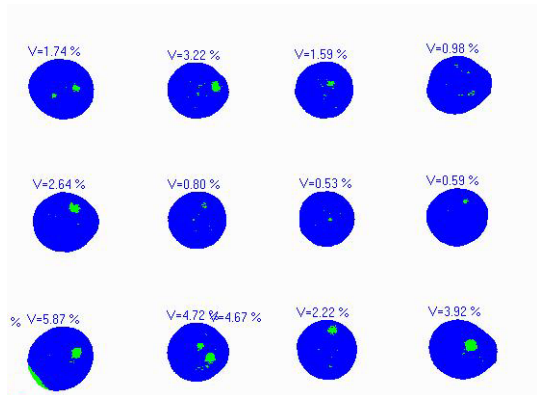


SN324 SAC balls/solder
0 - 2 void percent





SN332 SAC balls/SACB solder
0.6 - 6 void percent



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Lessons Learned

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Lessons Learned

- Components are critical!
  - XRF was used to verify the surface finish of components.
  - Lead-free components have different moisture sensitivity ratings.
  - Logistics: Tight control of parts and solder was required.
  - Because components are not marked for lead-free solder, some components were marked to differentiate between surface finish.

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Lessons Learned Continued

- Solder paste printing process does not require changes when using lead-free solder.
- Component placement process does not require changes for lead-free solder.
- Reflow as expected is the major process difference.
  - Lead-free solder's full liquidus temperature is approximately 38 degrees higher than SnPb; but the components and board thermal properties have not changed.
  - The decreased process window made thermal profiling a challenge.
    - High temperature insulation thermocouples will be necessary for future work.
  - The conveyor speed was slowed down and zone temperatures increased by 20-60°C depending on oven zone.
  - Visual examination in some cases is not a good indicator whether the reflow has been accomplished; have to rely on temperature and time.
    - Lead-free solder joints have a grainy appearance, some are not as shiny, the foot of the lead on surface mount components are more visible, and they don't wet out like SnPb.

Lessons Learned Continued

- Touch-up soldering is similar to SnPb
  - higher temperature (700°C) tips are required
- Cleaning was similar for all assemblies
- Quality Inspection:
  - The solder joint appearance varied from baseline SnPb due to the different wetting characteristics.
  - Additional training is required and our acceptability documents must be revised.
  - Visual aids would be helpful (acceptability pictures).

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Issues

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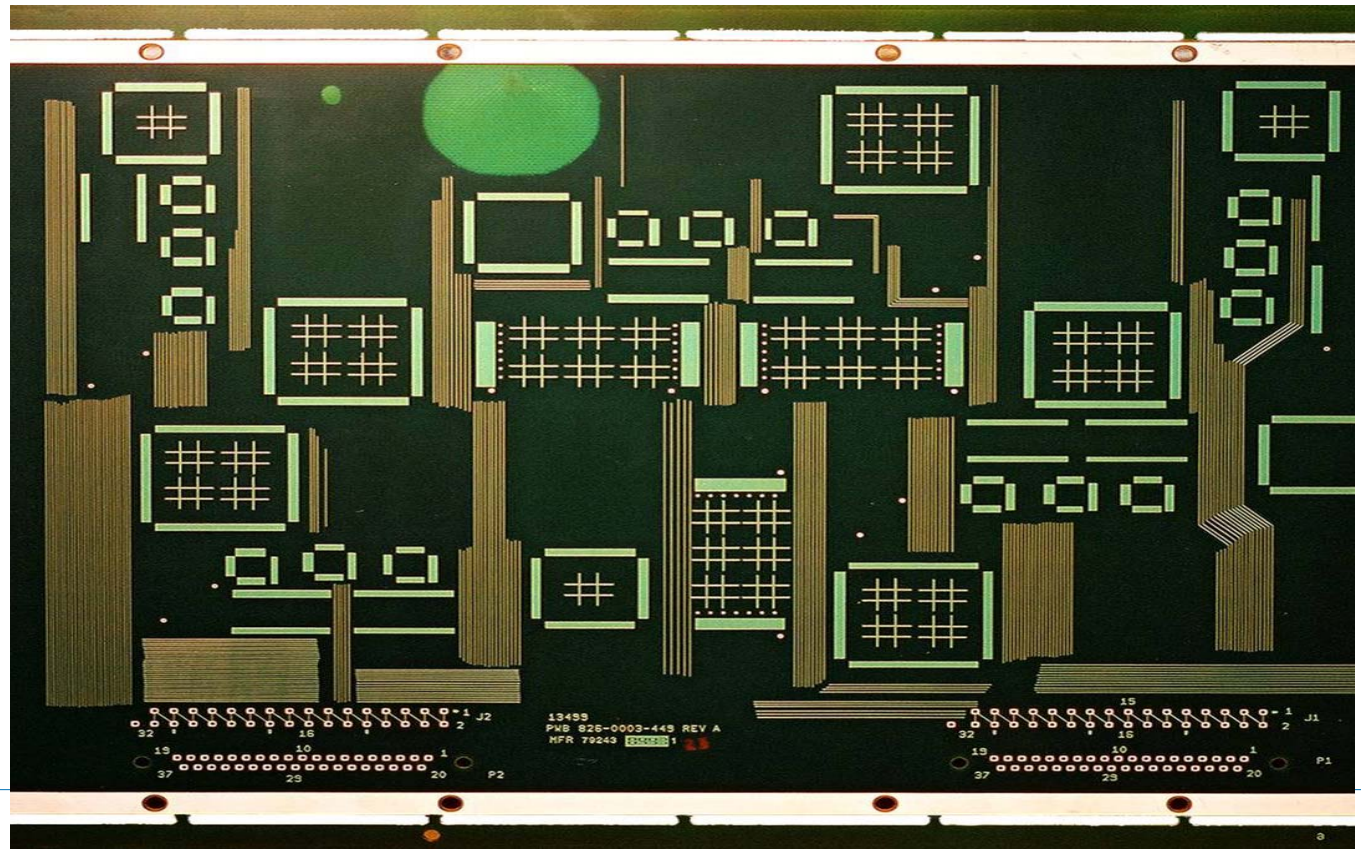
Issues

- Delamination was visible on SN331 after SACB reflow. The remainder of the PWBs soldered with SACB were baked for 3 hours at 230 °F.
  - Contamination can be seen at the delaminated area
  - No other boards were baked



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Issues

- Leads on the hybrids were skewed and not co-planar
  - Each hybrid had to be formed by hand before placement
  - The leads were straightened per D906-00004

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Final Comments

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Testing

Test		Performed By
Vibration	MIL-STD-810F, METHOD 514.5, PROCEDURE I	Boeing-Seattle
Thermal Cycling -55^{o}C to +125^{o}C	IPC-SM-785	Rockwell Collins

Acknowledgements

The following JG-PP/JCAA companies provided technical support and/or materials that made this effort possible:

- ACI – Pb-free skill training for hand soldering
- BAE Systems Irving – factory time and labor expenses
- Boeing-Seattle – technical support
- Florida CirTech, Inc. – materials
- Global Stencil – stencil services
- Heraeus – materials
- Rockwell-Collins – provided board design, procurement of components and bare boards
- Senju Solder – materials
- Raytheon- materials

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Contact Information:

ana.campuzano-contreras@baesystems.com

3131 Story Road
Irving, TX 75038

(972)659-2546